MODELLING PROJECT FEASIBILITY ROBUSTNESS BY USE OF SCENARIOS

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By

Claus Rehfeld, Assistant Professor & Steen Leleur, Associate Professor
Institute of Planning, Transport Studies
Technical University of Denmark
Building 115, DK-2800 Lyngby, Denmark
Email: crehfeld@ivtb.dtu.dk; sleleur@ivtb.dtu.dk
Telephone. (+45) 45 25 15 00, Fax. (+45) 45 93 64 12

Abstract

This paper presents a new scenario-based appraisal methodology (SEAM), which has been developed for transport infrastructure planning. SEAM aims at dealing with uncertainty in the planning environment in a more systematic way than is usually the case when applying scenario analysis. Specifically, SEAM secures a consistent inclusion of actual scenario elements in the quantitative impact modelling and facilitates a transparent project feasibility robustness analysis. SEAM is implemented as part of a decision support system with a tool-box structure applicable to different types of transport investment analysis.

Following a brief introduction in section 1, section 2 presents the model principles based on four scenarios which have been developed in a recent Danish scenario study: (I) the Market-oriented scenario, (II) the Intimate scenario, (III) the Supra-national scenario and (IV) the Technological scenario. The appraisal criteria relate to the present EU research on infrastructure evaluation as a criteria set being developed in the ongoing EUNET project is made use of. SEAM is illustrated by use of the Harbour Tunnel project in Copenhagen. It is demonstrated that SEAM can provide evaluation information that cannot be obtained by a more traditional approach. Special concern is given to evaluation results interpreted on the basis of a project robustness graph and a scenario sensitivity graph.

The third and final section contains the conclusions and outlines the perspective for the further development of SEAM.

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1 Introduction

This paper presents a new scenario-based appraisal methodology (SEAM), which has been developed for transport infrastructure planning. SEAM aims at dealing with uncertainty in the planning environment in a more systematic way than is usually the case when applying scenario analysis. Specifically, SEAM secures a consistent inclusion of actual scenario elements into the quantitative impact modelling and facilitates a transparent project feasibility robustness analysis. SEAM is implemented as part of a decision support system with a tool-box structure applicable to different types of transport investment analysis.

As a basis for the work with SEAM a review has been carried out to define scenarios in an appropriate way (Ayres, 1969; Schofer & Stopher, 1979; Rosenhead, 1980a, 1980b; Schnaars, 1987; Pearman, 1988). This has led to the following definition of a scenario in this context (Rehfeld, 1998):

> *A scenario is a plausible description of the exogenous (economic, social, environmental, political and technological) conditions in a possible and probable future with attention to timing.*

This definition implies that the preconditions for the models and variables are all within influence of the actual scenario. The definition is made use of in the SEAM methodology to determine its so-called development variables, which play a major role in the model set-up as described in the following.

2 A scenario-based appraisal methodology (SEAM)

The rationale behind the scenario-based appraisal methodology (SEAM) is to ‘envelop’ the planning uncertainties on the basis of the interdependencies between models and scenarios. The methodology elaborates on the scenario and modelling interrelationship in the context of transport planning by ‘painting’ the appraisal system in accordance with each scenario. SEAM thus aims at embracing these complexities through a collective evaluation of a project within multiple scenarios. The scenario painting of the appraisal methodology relates to multiple levels within it. The structure of the SEAM methodology is given in Figure **Fehler! Unbekanntes Schalterargument.**:

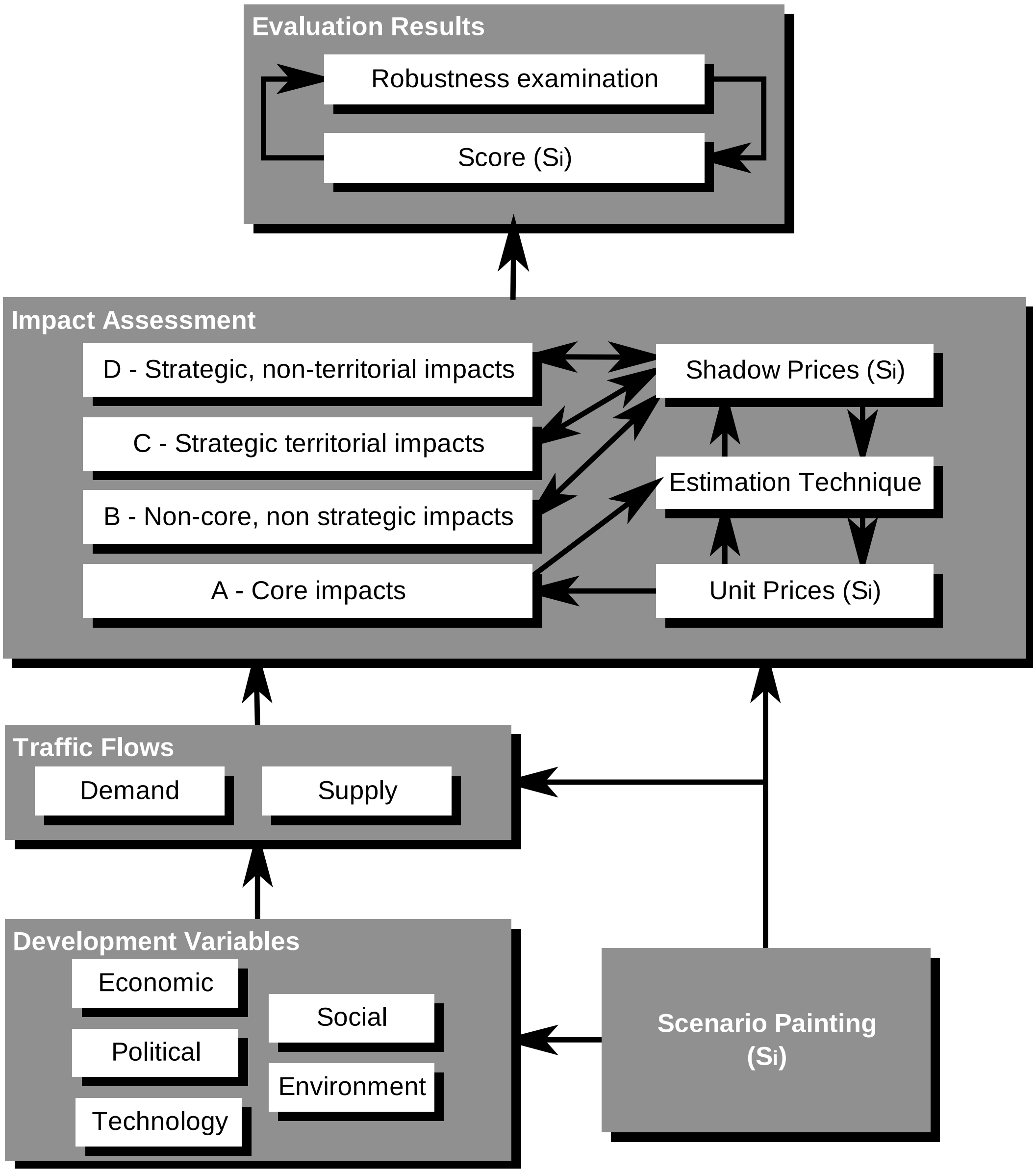

Figure **Fehler! Unbekanntes Schalterargument.** The structure of the scenario-based appraisal methodology (SEAM).

The SEAM methodology includes and utilises existing project appraisal techniques as part of the developed scenario-based approach. It draws on systems analysis through the description of a comprehensive modelling structure in order to describe the interdependencies in the planning system. It applies the argumental basis from sensitivity analysis, but promotes a wider understanding of project uncertainty. Finally, it applies estimation techniques from multi-criteria analysis for the assessment of so-called cross-sectional shadow prices, with these prices relating to the non-valuated part of the criteria set applied. The methodology involves several separate layers of which three elements that especially characterise SEAM will be discussed in most detail below:

- Scenario painting of development variables
- Impact assessment (unit prices, shadow prices and estimation techniques)
- Evaluation results

2.1 Scenario painting of development variables

Development variables refer to relevant variables in the planning environment. Some variables influence travel behaviour directly whereas others have a more indirect influence. The level of income, the car ownership, legislation and taxation are variables that have a direct influence. Other variables influence the development variables indirectly through e.g. increases in the efficiency of the transport system. Then again other variables influence the intensity of the external impacts of the transport system. The exogenous assumptions may, however, also affect the internal relationship between models in the modelling system. Assuming for example that cars become far quieter than we know them today, this will positively affect the noise impact. Conversely, it may also have a negative impact on the expected number of accidents, as e.g. pedestrians are not forewarned by the noise of approaching vehicles.

This interconnectedness within the planning environment and the attempt to describe it forms the basis of rational comprehensive planning. The systems analysis approach also attempts to embrace the causal interaction between the appraisal model system and the planning environment. The difference between systems analysis and SEAM is that systems analysis is used for systems prediction whereas SEAM aims at assessing the logical structure within each scenario to form a basis for a judgmental setting of the scenario relevant variables.

The determination of cause and effect in socio-cultural systems is highly complex and may involve several feedback loops. The feedback between development variables in the planning environment also involves a certain level of inertia. Some development variables may be interpreted to make swift responses whereas others are rather slow. Especially if the response involves a chain of variables or changes in attitudes the time lag may be substantial. Scenarios are often constructed with a specific year in mind and are rarely concerned with the development profile: In the specific scenario year 20xx in the planning period the behavioural pattern will be this or that.

Some of the elements of a scenario do from the present point of view seem more or less obvious in the sense that elements of the scenario are imaginable in the near future (this should not be confused with the likelihood of a scenario which relates to the scenario target year). Other scenarios appear more obscure and will presumably take longer time to mature before being fully fledged. Yet again other scenarios involve changes that seem vague and are more evenly distributed over time. Also, a trend may prevail in the point of departure (base year) but the scenario will determine the finishing-point (target year). To accommodate these interrelationships SEAM makes use of development variables for which the change from the base year to the target year is determined by a judgmental application of a range of functions:

- Linear (‘vague’ or ‘evenly distributed’)
- Exponential / percentual (‘slow development at first’ whereafter ‘it accelerates’)
- Logistical (‘very quick/revolutionary change in the medium term’)
- Power (‘very slow/fast development at first’ and then it becomes ‘very fast/slow’ depending on the power parameter applied)
- Polynomial / customised (development profile specifically ‘adjusted to the planning context’)

Additional functions so far in the development of SEAM have been considered unnecessary as the above mentioned cover a ‘satisfactory’ range of options. The assessment of the development profile will necessarily be based on professional judgement in a dialogue with the decision-makers.

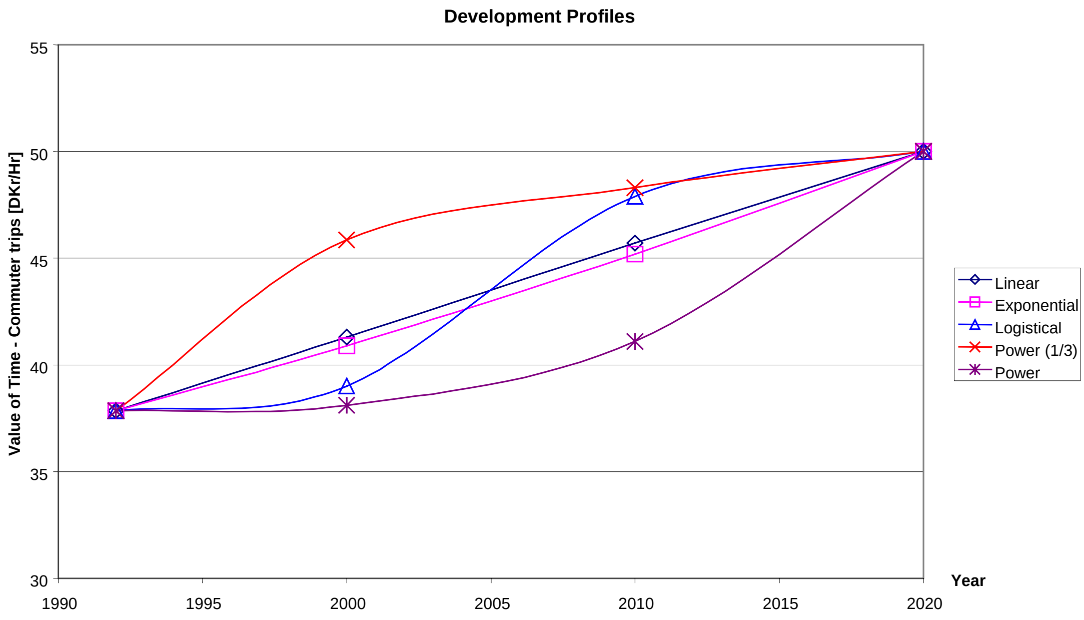

Figure **Fehler! Unbekanntes Schalterargument.** Example of development profiles for the value of time for commuter trips. The examples are taken from the market-oriented scenario (MKT) (to be described in section 2.2) where the value of commuting time increases from 37.86 to 50 DKr/Hour. The Logistical curve was developed using an approximation based on two power functions (power 3). The exponential function had a growth rate of approximately 1% p.a. One of the power function curves is based on a power of 1/3 and the other on a power of 3.

The development profile should be assessed and set with great care as to avoid significant inconsistencies in-between the actual calculation years. It is important to note that not all variables evolve along the same profile in each scenario. This may in the medium term lead to inconsistencies. Special care should be taken in assessing whether such inconsistencies are too severe. In that case certain variables will need a customised development profile which is also possible with the developed SEAM software.

2.2 The scenarios

A possible composition of development profiles within a number of scenarios will be illustrated through an example. The development variables involve model variables, unit prices as well as weights (for the multi-criteria model applied). The scenarios made use of are four Danish scenarios constructed by Palludan et al. (1996). The four scenarios as they are interpreted here are:

- The Market-oriented scenario (MKT)
  A ‘liberal’ scenario involving de-regulation in all sectors and high economic growth.
- The Intimate scenario (INT)
  A ‘social’ scenario in which attitudes change towards the local values and local environment.
- The Supra-national scenario (SUP)
  A ‘political’ scenario where the global environment is a global concern and the European Union and the United Nations play a central role.

- The Technological scenario (TEC)
  The 'technological' scenario in which a technological jump occurs and a technology friendly society evolves.

In addition to the four scenarios a Base scenario has been applied as well. The Base scenario involves a continuation of current preferences without any developments. The Base scenario is used as a point of reference to the other scenarios as seen in section 2.5.

The example is limited to the analysis of the impact assessment for road transport since it has been beyond the available resources of this study to consider all model aspects.

2.3 Traffic flows

The traffic flows may be assessed using any traffic model. For the actual case calculations a recent comprehensive traffic model for Copenhagen was used (Nielsen, Nielsen & Israelsen, 1998).

2.4 Impact assessment

As criteria set the EUNET Transport Evaluation Frameworks have been used. Four main groups of impacts apply here (Leleur et al., 1998):

- Core impacts (A-impacts)
  Basic impacts comprising transport economic and local environmental impacts.
- Non-core, non-strategic impacts (B-impacts)
  'Soft' mode specific impacts relating to the transport quality and the visual environment.
- Strategic, territorial impacts (C-impacts)
  Impacts with territorial affiliation such as mobility considerations, economic growth and global environment.
- Strategic, non-territorial impacts (D-impacts)
  Other strategic impacts with no territorial affiliation such as technology development and other policy and planning issues.

The EUNET framework for inter-urban road infrastructure projects is seen in table 1.

FV 11-I LMS	Road infrastructure project types VARIABLES
Impacts	**Inter-urban**
Core impacts	
A1 Investment costs	Materials, labour, land and property acquisition (including compensation)
A2 System operating and maintenance costs	Structural repairs, carriageway delineation, signing, enforcement of traffic regulations
A3 Vehicle operating costs	Fuel and oil consumption, tyre wear, vehicle maintenance, depreciation
A4 Travel time benefits	Working time, home-work time and leisure time
A5 Safety	Fatalities, severe and slight injuries, damage only accidents
A6 Local environment	Noise and air pollution, severance
Non-core, non-strategic impacts	
B1 Driver convenience	Comfort, stress, smoothness
B2 Urban quality & landscape	Visual environment
Strategic, territorial impacts	
C1 Strategic mobility	Accessibility and networks
C2 Strategic environment	Greenhouse effect, strategic atmospheric pollution, loss and damage of ecological, historical, archaeological and scientific sites, energy consumption, natural resources
C3 Strategic economic development	Land use, economic development, employment impact
Strategic, non-territorial impacts	
D1 Private financial attractiveness	Financial internal rate of return, net present value or equal
D2 Other strategic policy and planning impacts	Conformity to other strategic policy and planning concerns

Table **Fehler! Unbekanntes Schalterargument.** EUNET framework for inter-urban road infrastructure projects: Variables (Leleur et al., 1998).

Some of the impacts are well defined and with monetised values (referred to as valuated impacts). These may be used directly in a cost-benefit analysis as is the case for the A-impacts. The other impacts are, however, not easily monetised and are often not well defined from a modelling point of view. In SEAM these impacts (referred to as non-valuated impacts) are determined by an appropriate MCA model for this purpose, the WARP method (Jensen & Leleur, 1989).

2.5 Evaluation results

In SEAM the evaluation results are obtained in the following way facilitated by a PC software. After the scenario painting of the development variables each infrastructure project can be evaluated with respect to its net present value (NPV) for each scenario. The actual case concerns the Copenhagen Harbour Tunnel project where the following project alternatives are considered:

PROJECT	**DESCRIPTION**	**COST**
2c	Amager Strandvej alternative: Harbour Tunnel combined with an upgrade of the road to Copenhagen Airport and the Øresund Bridge between Denmark and Sweden	2.3 Billion DKr.
2d	Equal to 2c, but with traffic calming measures in central Copenhagen	2.5 Billion DKr.
4a	Ring road alternative: Harbour Tunnel as part of a complete ring road around Copenhagen. No ring road exists today	3.1 Billion DKr.
4b	Equal to 4a, but with traffic calming measures in central Copenhagen	3.3 Billion DKr.

Table **Fehler! Unbekanntes Schalterargument.** Project alternatives and rough estimates of their cost in billion DKr. (1995 – price level). The prices are based on assessment s undertaken by the Danish Ministry of Transport and the Danish Road Directorate (Trafikministeriet, 1995; VD, 1995)

The project alternatives are indicated on the map below showing the core area of Copenhagen, with the city centre, the harbour and Amager. The alternatives will in different ways relocate traffic flows.

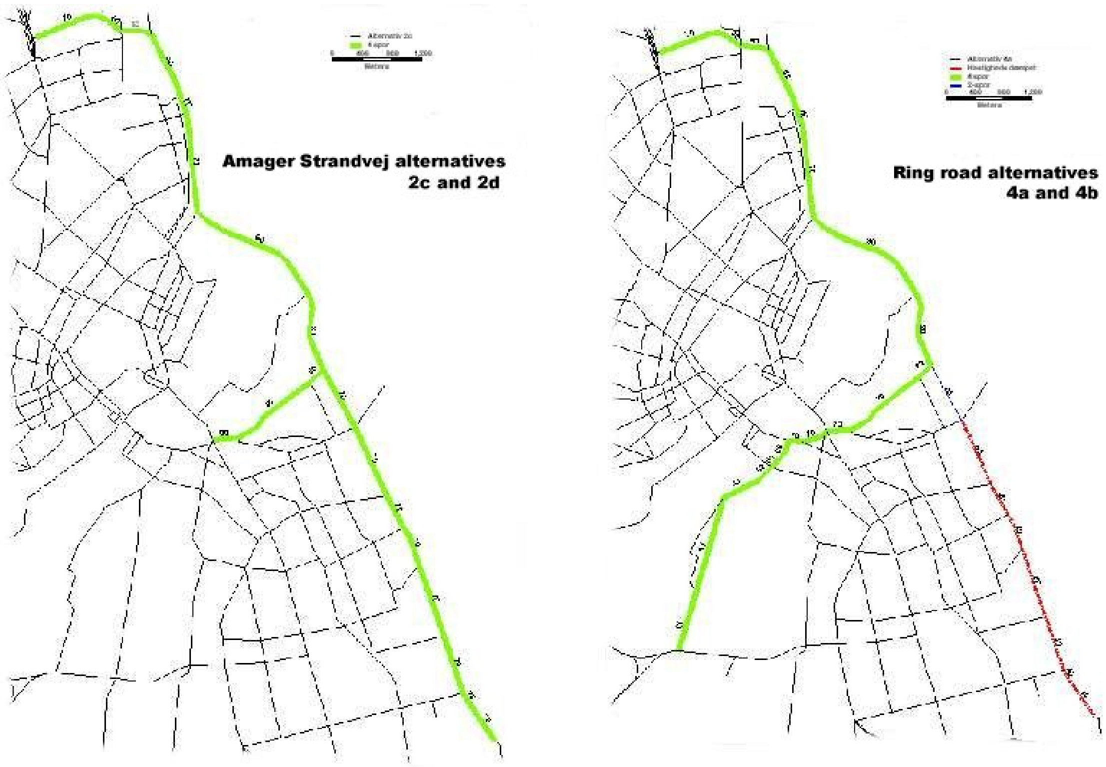

Figure **Fehler! Unbekanntes Schalterargument.** A graphical presentation of the project alternatives. The lower right part of the map shows the island Amager whereas the upper left part is central Copenhagen. To the right is the sea dividing Denmark and Sweden.

The SEAM methodology involves the painting of multiple variables throughout the modelling system. The planning problem involves the evaluation of four projects that have been assessed by a traffic model for four calculation years. 10 different impact models for four different scenarios and a base scenario have been used to assess each project. This led to $4 \cdot 4 \cdot 10 \cdot 5 = 800$ impact assessments. As the planning process is well known not to be a linear process, but far more searching and learning (Leleur, 1995) the impact assessment may also have to be repeated several times. A structured and efficient approach to the data and model management of such a system is required as it is to the presentation and interpretation of the evaluation results.

The SEAM software includes a visualisation procedure that makes it possible to undertake a scenario-based appraisal supported by a graphical inspection of the evaluation results. In this manner SEAM performs a scenario-based envelopment of the planning uncertainty. Interpretation of the results leads to an assessment of the robustness of the individual project alternatives.

The SEAM methodology does not aim at making an analytical assessment of robustness as originally suggested by Gupta & Rosenhead (1968), nor does it aim at presenting the planning uncertainty by way of probabilities that are linked together. Robustness is in SEAM an interpretation of graphically presented project scores in the specific planning context. This is illustrated below in Figure **Fehler! Unbekanntes Schalterargument.** for the Copenhagen Harbour Tunnel case.

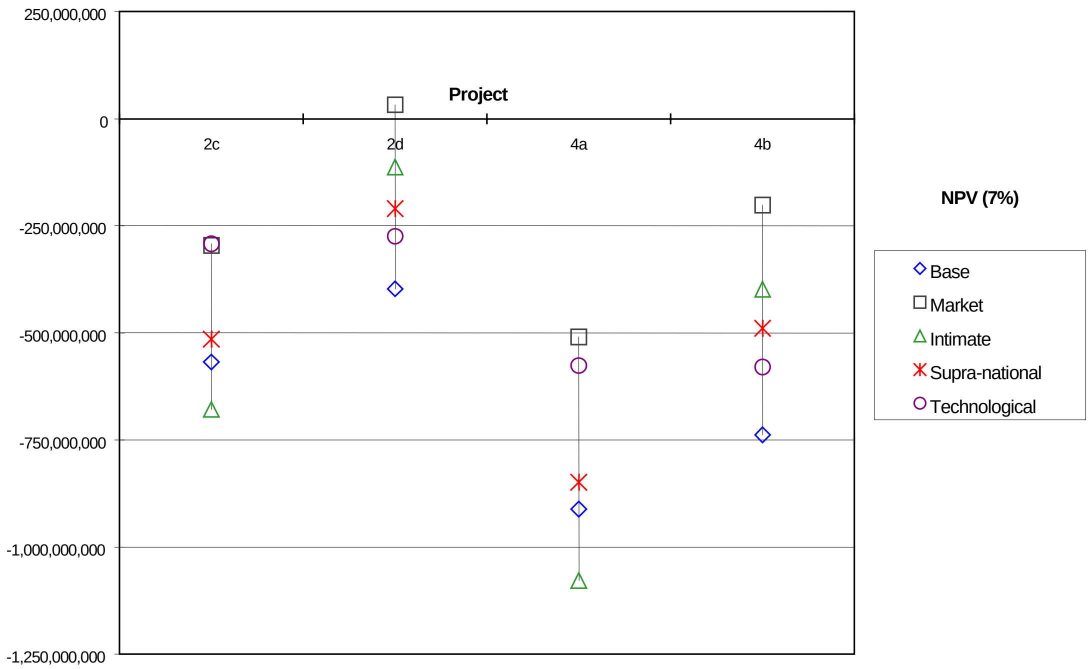

Figure **Fehler! Unbekanntes Schalterargument.** An example of a graphical SEAM presentation of project robustness (project robustness graph). It can be seen that none of the project performs well (Rehfeld, 1998).

The graphical presentation of the project scores by scenario illustrates the difference between robustness ('interval') and project performance ('single value'). The analysis of robustness is based on a comparative analysis between projects in a specific pool and not on some definite measure. No single score for project performance is provided only a range of values (interval) expressing its robustness. The determination of threshold values for minimum project performance (minimum score value) could be part of the decision making process.

The overall planning uncertainty has been enveloped on the basis of the painting of the planning environment. This envelopment of planning uncertainty underlines the importance of the applied scenarios and their interpretation into consistent sets of development variables. The effect the different uncertainty elements have on the final project outcome is embedded in the robustness measure as a range of values.

In addition to the project robustness graph another type of graphical presentation – the scenario sensitivity graph – can give valuable information as seen in Figure **Fehler! Unbekanntes Schalterargument.** below.

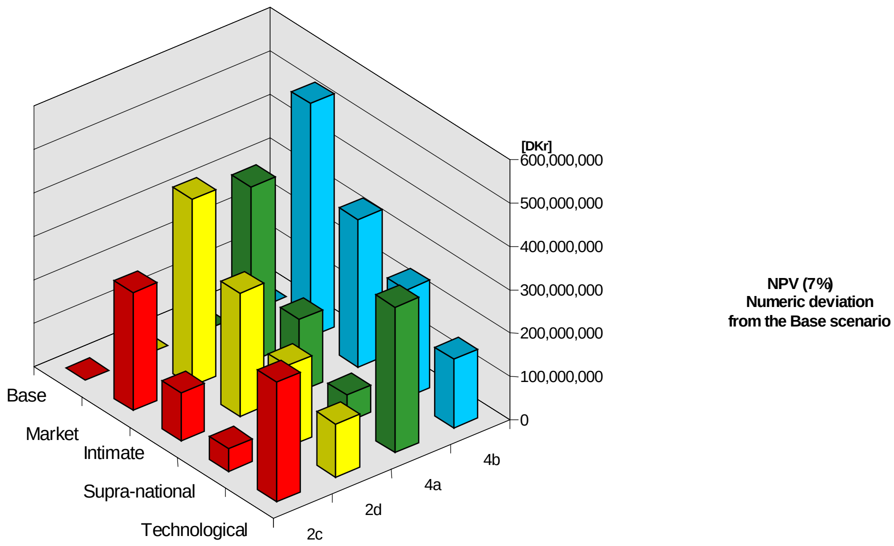

Figure **Fehler! Unbekanntes Schalterargument.** An example of a graphical SEAM presentation of scenario sensitivity (scenario sensitivity graph)

This type of presentation shows the scenario sensitivity of the different projects. The graph is based on a comparison between the underlying Base scenario and each of the applied scenarios. The graph does not show whether a project performs better or worse than it does in the Base scenario since the graph is based on the numeric difference. What it does depict, is the sensitivity of each project with respect to each scenario. As seen the projects denoted 2c and 4a are obviously more sensitive towards the Technological scenario (TEC) than the projects 2d and 4b, whereas all projects appear sensitive towards the Market-oriented scenario (MKT). The scenario sensitivity graph illustrates qualities of the benefit distribution and reveals the influence this has on project uncertainty.

3 Conclusions and perspective

The SEAM appraisal methodology has been developed so that it incorporates interdependencies between scenarios and models. In this way SEAM acknowledges the influence from possible futures and makes it possible to carry out a scenario-based envelopment of the planning uncertainty. One premise underlying the development is that a graphical interface can play a major role as part of a decision support system for transport investment planning. In this respect two types of graphs have been worked out as part of the methodology: The project robustness graph and the scenario sensitivity graph. From the applications so far it can be concluded that SEAM with these graphical features and its flexibility to model on the basis of scenarios, seems to hold a promising potential as concerns its further development and applications.

As part of the development perspective can be mentioned the evaluation of European transport corridors where actual use on the corridor Copenhagen-Stockholm has been initiated. This case is part of the CODE-TEN project within the Strategic Part of EUs 4'th Framework Programme. Other corridor cases are also included in CODE-TEN and SEAM may be further applied also on these other corridors where the experience to be gained from the Copenhagen-Stockholm application can be made use of.

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